ACOUSTIC AND NON-ACOUSTIC PERFORMANCE OF COAL BOTTOM ASH AS SOUND ABSORPTIVE MATERIAL FOR REDUCING RAILWAY NOISE LEVEL

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PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

DEDICATION

I dedicate this dessertation to my loving parent
Abah and Mama
My sweet husband Ahmad Fattah Al Islam
My sons
My supportive supervisor Ts. Dr. Shahiron Shahidan
Who has offered unwavering support, love, encouragement
and prays of day and night during the past four years of my doctoral journey.
Thanks Mama Abah
for always believing in me and for encouraging me to strive my dreams
Thanks my dear lovely husband
caused always cheered me on when I was discouraged,
wiped my tears away when the great research catasrophes stuck and he has most
importantly been 100% confident in my ability this get this done.
Along with all hard working and respected lectures and friends.
Thank you very much and love you all.

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

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PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

ABSTRACT

The development of new technology and rapid development in many countries have led to various types of pollution, especially acoustic pollution in urban areas. Furthermore, the huge production of Coal Bottom Ash (CBA) is treated as waste and often placed into impoundment ponds, silos or landfills, which has contributed to environmental issues. Usage of CBA in concrete production in reducing railway noise pollution reduce the environmental pollution. This study presents the acoustic and non-acoustic performance for a new concrete product that consists mainly of CBA. Grade 30 MPa concrete was cast with varying replacement percentages (0% to 100%) of CBA as fine aggregate replacement in concrete mixture. The specimens were cured for periods of 7, 28 and 90 days. The non-acoustic performance of CBA concrete demonstrated similar or even better performance than normal concrete by conducting compressive strength, splitting tensile strength, water absorption, water permeability and ultrasonic pulse velocity. The increase in CBA percentage in the concrete mixture has affected the compressive strength and splitting tensile strength of the sample which were lower than that of control concrete. CBA concrete can be recommended as good concrete due to its absorption properties. Based on the sound test conducted according to ISO 11654: 1997, it was found that CBA concrete can be classified as Class D (absorption). Class D materials are able to absorb more than 30% of sound by conducting impedance tube and reverberation time. In addition, the Noise Reduction Coefficient (NRC) performance for CBA concrete addresses more than 35% of the absorbed railway sound. CBA concrete showed an improvement in acoustic properties compared to normal concrete as it is able to reduce up to 3.74 dB of the existing railway noise level while normal concrete can only reduce up to 1.94 dB of the existing noise level.

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

ABSTRAK

Pembangunan negara yang semakin maju dan canggih dengan teknologi baru telah mendatangkan pelbagai jenis pencemaran antaranya pencemaran bunyi hingar terutamanya di sekitar kawasan bandar. Selain itu, pengeluaran sisa arang batu iaitu abu arang bawah (CBA) yang semakin membimbangkan yang telah dihasilkan dianggap sebagai sisa dan sering dibuang di dalam kolam timbunan, silo atau tapak pelupusan yang telah menyumbang kepada isu-isu alam sekitar. Penggunaan CBA dalam penghasilan konkrit bagi mengurang pencemaran bunyi kereta api mampu mengurangkan pencemaran alam sekitar. Kajian ini dilakukan untuk mengkaji prestasi akustik dan bukan akustik bagi konkrit yang dihasilkan daripada campuran sisa arang batu. Campuran konkrit bergred 30 MPa dihasilkan dengan pelbagai variasi peratusan penggantian (0% sehingga 100%) dari CBA sebagai pengganti kepada agregat halus (pasir) di dalam campuran konkrit. Spesimen tersebut telah diawet selama 7, 28 dan 90 hari. Berdasarkan ujian yang telah dilakukan ianya mendapati bahawa prestasi konkrit campuran adalah sama atau lebih baik daripada konkrit biasa dengan melakukan ujian kekuatan mampatan, kekuatan tegangan, peyerapan air, kebolehtelapan air dan halaju nadi ultrasonik. Peningkatan jumlah peratusan CBA dalam campuran konkrit telah mempengaruhi kekuatan mampatan dan kekuatan tegangan yang lebih rendah daripada konkrit biasa. Selain itu, kadar serapan air dan penyusupan air bagi konkrit campuran CBA adalah lebih tinggi daripada konkrit biasa. Kadar serapan air bagi konkrit CBA meningkat apabila peratusan penggunaan CBA di dalam konkrit meningkat. Hasil ujian bunyi yang dilakukan terhadap konkrit campuran CBA mendapati nilai serapan bunyi adalah di kelas D (ISO 11654:1997). Selain itu juga, prestasi pekali pengurangan bunyi (NRC) bagi konkrit campuran CBA menunjukan lebih daripada 35% bunyi diserap. Ianya juga telah menunjukan potensi yang baik dari konkrit biasa iaitu kemampuanya untuk mengurangkan kadar bunyi keretapi sebanyak 3.74 dB berbanding konkrit biasa 1.94 dB.

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

CONTENTS

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

LIST OF TABLE

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

LIST OF FIGURE

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

LIST OF SYMBOLS AND ABBREVIATIONS

dB	-	Decibel
dBA	-	A weighted decibels
Am	-	Ante meridiem (Before noon)
Pm	-	Post meridiem (After noon)
kPa	-	Kilo pascal
Pa	-	Pascal
α	-	Sound absorption coefficient
α_{pi}	-	Arithmetic mean value of sound absorption coefficient
α_w	-	Weighted absorption coefficient
α_s	-	Sabine's absorption coefficient
m	-	Meter
mm	-	Millimeter
kg	-	Kilogram
S	-	Second
W	-	Watt
MW	-	MegaWatt
GW	-	GigaWatt
%	-	Percent
Hz	-	Hertz
ACAA	-	American Coal Ash Association
ASTM	-	American Society for Testing and Materials
BS	-	British Standard
CBA	-	Coal Bottom Ash
CBAC	-	Coal Bottom Ash Concrete
CO_2	-	Carbon dioxide
DOE	-	Department of Environment
EHS	-	Environmentally Hazardous Substance
EN	-	European Norm
EQA	-	Environment Quality Act

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

ERL	-	Expres Rail Line
ETS	-	Electric Train Service
FBA	-	Fine Bottom Ash
FGD	-	Fuel Gas Desulphurization
IPP	-	Independent Power Producers
ISO	-	International Standards Organization
KTMB	-	Keretapi Tanah Melayu Berhad
MPa	-	Mega Pascal
MRT	-	Mass Rapid Transit
MSW	-	Municipal Solid Waste
NRC	-	Noise Reduction Coeffieicent
NRDs	-	Noise Reduction Device
PCC	-	Portland Cement Concrete
RHA	-	Rice Husk Ash
RT	-	Reverberation Time
SAC	-	Sound Absorption Coefficient
SCC	-	Sel- compacting concrete
SEM	-	Scanning Electron Microscopy
SF	-	Silica Fume
SLM	-	Sound Level Meter
SPAD	-	Suruhanjaya Pengangkutan Awam Darat
SW	-	Schedule Waste
TNB	-	Tenaga Nasional Berhad
UPV	-	Ultrasonic Pulse Velocity
WBA	-	Washed Bottom Ash
XRF	-	X-Ray Fluorescent

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Noise is one of the most negative impacts of transport affecting the quality of the environment. It affects a large number of people as it often causes annoyance and irritation which affect various human activities. Noise pollution from the transportation sector can interfere with the environment. Even though railways are one of the most environmentally friendly types of transportation due to its energy efficiency and emittance of less hazardous substances, railway noise produced by freight trains, speed trains and high-speed trains remains a major environmental issue. The investigation of railway noise is getting more attention among researchers as it is continuously reviewed from year to year starting from 2010 to 2019.

In Malaysia, a handful of studies are limited to surveys of railway noise status and its influence on the community. However, various techniques can be employed to reduce railway noise at source including dampers, sleepers, barriers, tunnels and so on. A noise barrier wall is one of the most economic and innovative methods for reducing noise. Many industries have come out with many types of noise barriers which can be built out of wood, concrete, masonry, metal and transparent materials. It also comes in various shapes such as hollow blocks or panels. However, based on previous research, noise barriers made of recycled aggregate, recycled rubber, recycled ceramic industry waste and other types of waste have also been invented.

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

Waste has long been a major issue for the environment, the society and the economy (Arenas *et al.*, 2015). Industrial waste poses a potential serious hazard to the environment as most industrial processes employ chemicals or chemically produced materials (Aja *et al.*, 2016). In Malaysia, the manufacturing sector was first identified as generators of toxic and hazardous waste which is an environmental hazard for living things. Due to rapid development, the quantity of solid waste generated every year continues to increase. The quantity of solid waste in Malaysia is projected to increase from 19,100 tonnes per day in 2005 to 30,000 tonnes per day by 2020 with the annual population growth rate 2.5 per cent (Ali *et al.*, 2018)

One of the manufacturing activities that contribute to the generation of industrial waste is electricity power generation. Due to the increasing demand for electricity every year, several coal fired thermal power plants have been set up in large numbers in the country to meet consumer demand (Singh & Siddique, 2013).

There are several coal power plants located in Malaysia namely Tanjung Bin, Jimah, Sultan Salahuddin Abdul Aziz/Kapar and Sultan Azlan Shah/Manjung coal power plant stations as shown in Figure 1.1. Most of these power plants have been using coal as the main source for generating electricity. This, in turn, produces large volumes of coal ash (Oh *et al.*, 2010). Fly ash, coal bottom ash (CBA), boiler slag and Flue Gas Desulphurisation (FGD) sludge are wastes produced during the combustion process in coal-fired power plants. According to Kockwood & Evans (2012), coal ash is a hazardous waste where the toxic remains of coal burning in power plants are full of chemicals that cause cancer, developmental disorders and reproductive problems. Coal bottom ash (CBA) is still being treated as solid waste material which is disposed of on open land and is not used in any form (Singh & Siddique, 2015).

The massive quantity of CBA produced from the coal combustion process for electricity generation poses a risk to human health and the environment. CBA can contaminate ground or surface water and subsequently poison living organisms. Therefore, CBA is gradually being incorporated in the construction industry as road base layers, pavements, structural fill, drainage media, aggregate for concrete and also in manufactured soil products to reduce environmental pollution (Kuo, Poon & Etxeberria., 2013). In previous research, CBA has been used as a partial replacement

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

of natural aggregates (fine aggregate or coarse aggregate). It possesses high fire resistance due to its wide evaporation plateau (Abubakar *et al.*, 2012a).

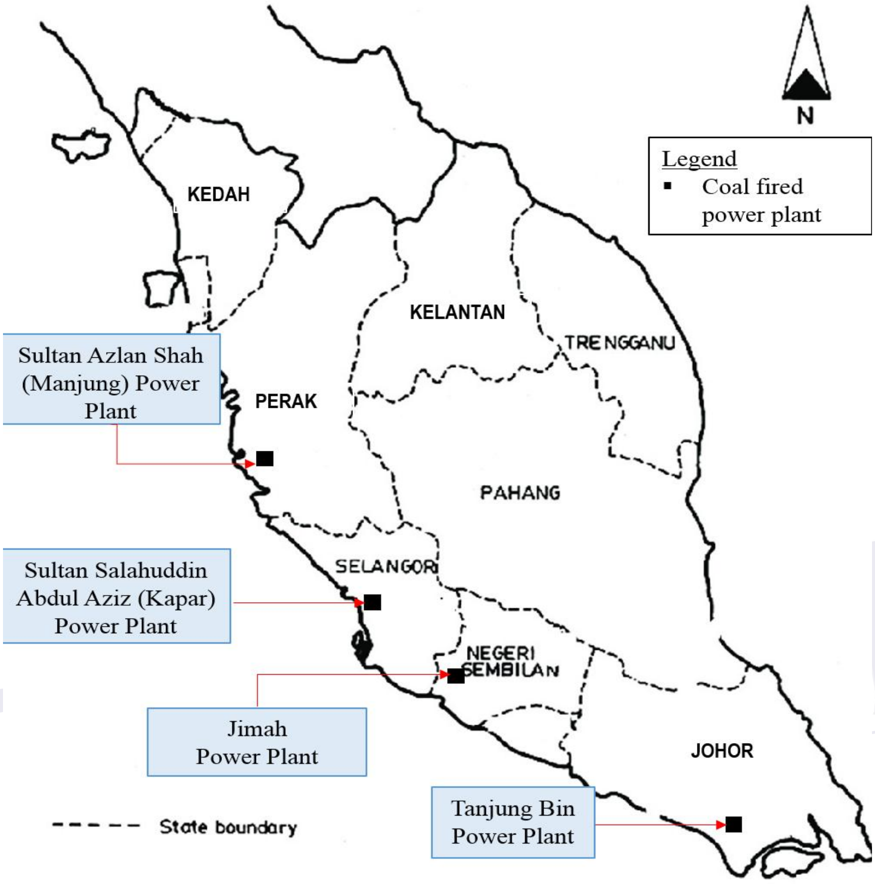

Figure 1.1: Location of coal-fired power plants in Malaysia (Edited from Muhardi *et al.*, 2010)

This research mainly studies the potential application of CBA in concrete which can hopefully be used as absorptive material in railway noise barriers. The usage of CBA as an absorbent material in concrete mixture has demonstrated similar properties to other conventional materials used for sound absorbing applications (Arenas *et al.*, 2013). Besides that, the findings of this study may also help reduce noise pollution which poses a risk to both humans and the environment.

1.2 Problem Statement

Coal is the main source used for the generation of electricity worldwide. According to Muhardi *et al.,* (2010), it has been recognised as an important source of fuel in Malaysia. The demand for coal for electricity generation increased sharply from an estimated 6.03 million tonnes in 2000 to between 19 to 20 million tonnes per annum by 2010 (Mohamed & Teong, 2010). It is also expected to increase by more than 30 million tonnes per annum by 2020. Coal remains one of the main sources for energy generation due to its low price and it being the most abundantly available fossil fuel in Malaysia (Suruhanjaya Tenaga, 2018).

CBA is one of the non-combustible materials that is produced after the coal combustion process for electricity generation. CBA is the coarser part which is collected at the bottom of the coal furnace. It consists of angular ash particles which are too heavy and large to be carried up into smoke stacks. Typically, CBA is simply disposed of on open land after the burning process. Due to coal combustion, an increased volume of CBA is continually being disposed of on land. The volume of CBA that is being disposed of is increasing by the year. According to the Department of Environment (DOE) Malaysia, 364,425.95 MT/year of coal ash was generated in 2010 while the total quantity of coal ash generated is 342,560.39 MT/year in 2011. This represents an increase of 6% in coal ash production in 2011. Meanwhile, in Tanjung Bin power plant has produced 50,000 metric tonnes of coal ash (fly and bottom ash) every month (Abdullah *et al.,* 2018).

Due to the huge amount disposal of CBA has contributed to environmental pollution such as the pollution of Emory and Clinch Rivers in Kingston, Tennessee. This also happened to Tanjung Bin power plant which is required large area for disposal storage of CBA (Abdullah *et al.,* 2018). The disposal of CBA have its disadvantages in the sense when the pond site is not lined with concrete has cause the heavy metals tends to leach into natural ground water and contamination to the environmental (Abubakar *et al.,* 2012). According to Gottlieb *et al.,* (2010), the water in the rivers contained heavy metals such as arsenic and elevated levels of other toxic metals such as lead, thallium, barium, cadmium, chromium, mercury and nickel. In

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

LIST OF APPENDIX

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

Malaysia, CBA is classified as Scheduled Waste SW 104 (Environmental Quality Act) and hazardous waste due to its toxicity.

On the other side, increase in human population and daily activities has caused traffic congestion, which is nowadays the biggest issue faced by road users. However, the Malaysian government has begun to gradually overcome the issues by providing more railways service in Malaysia. The railway services provided by the government help ease the public's movement in both urban and rural areas (Khalid *et al.*, 2014).

The demand for usage of trains among the public faces several challenging issues such as noise and vibration issues in residential areas as reported in Sinar Harian on 28 April 2016. According to the article, residents of Sri Teratai Apartment in Puchong Jaya claimed that noise from railway services has affected their daily activities. They had difficulty sleeping. Babies and the elderly were especially disturbed by the noise generated by trains. This also be supported by Fawwaz *et al.*, (2013) where found the residents that lived nearby LRT station Taman Melati also faced the same problem which is difficulties to sleep early due to the noise from LRT line which is close to their neighbourhood.

According to Shahidan *et al.*, (2017) most of measured noise levels of railways reached more than 90 dB which exceeds the permissible noise limit set by the Department of Environment (DOE) Malaysia. The noise limits for day and night are 60 dB and 50 dB respectively for noise sensitive areas or low density residential areas.

Considering the increase in noise emissions from railway services in residential areas, environmentally friendly materials is needed. For example, coconut shell powder and rubber ash as well as other waste products have been used in the construction industry especially in concrete production. Therefore, based on the issue highlighted, this study has selected CBA as absorptive material in reducing noise pollution. CBA is considered as a waste product which pollutes the environment.

CBA have been used in concrete production as cement replacement and fine aggregate replacement previous researchers. It has the potential to be used in concrete mixes. Most of researches used CBA to improve the mechanical properties of concrete such strength development and durability of the concrete since the findings shows the similar pattern with the normal concrete. Eventhough, there were research had been conducted by using CBA with different layer in the concrete production to improve

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

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